

The Canadian Experiment for Freeze / Thaw in 2012 or 2013 (CanEx-FT12 or FT13)

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Collaboratively:

Environment Canada (EC)

Institut National de Recherche Scientifique, U. Quebec, Canada (INRS)

Jet Propulsion Laboratory, California Institute of Technology (JPL)

United States Department of Agriculture (USDA)

National Aeronautics and Space Administration (NASA)

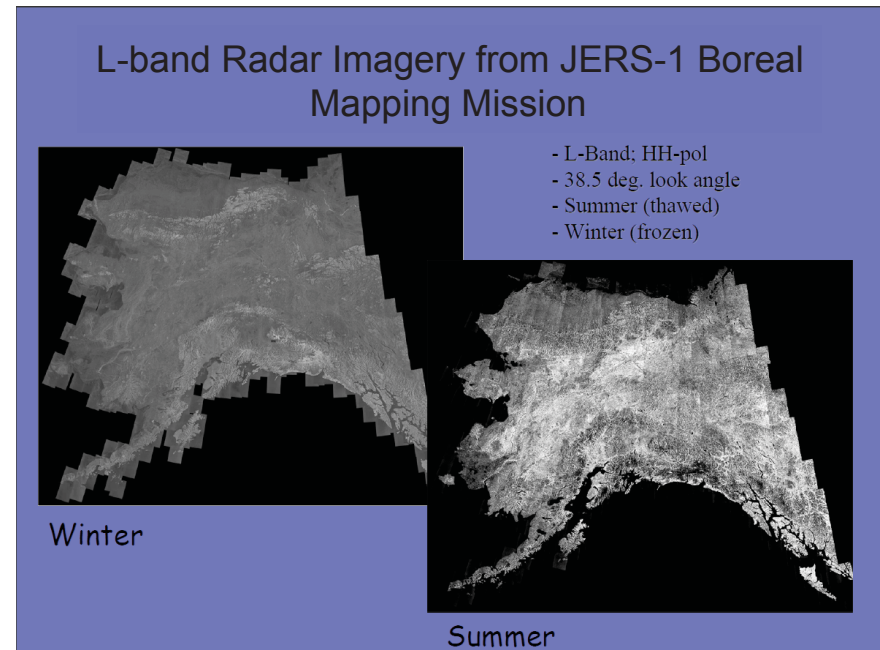
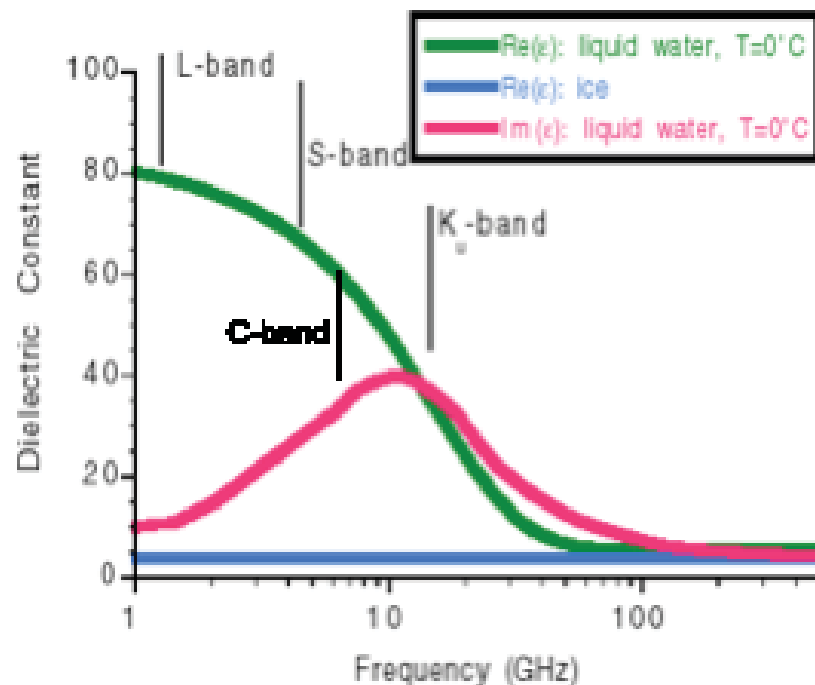
Canadian Space Agency (CSA)

GENERAL OBJECTIVES

- *Pre-launch Cal / Val of SMAP **F/T products** and retrieval algorithms*
- *Rehearsal for SMAP post launch validation*

L-Band SENSITIVITY to LANDSCAPE F/T

Large (3-7 dB) L-band signal response to landscape freeze-thaw events



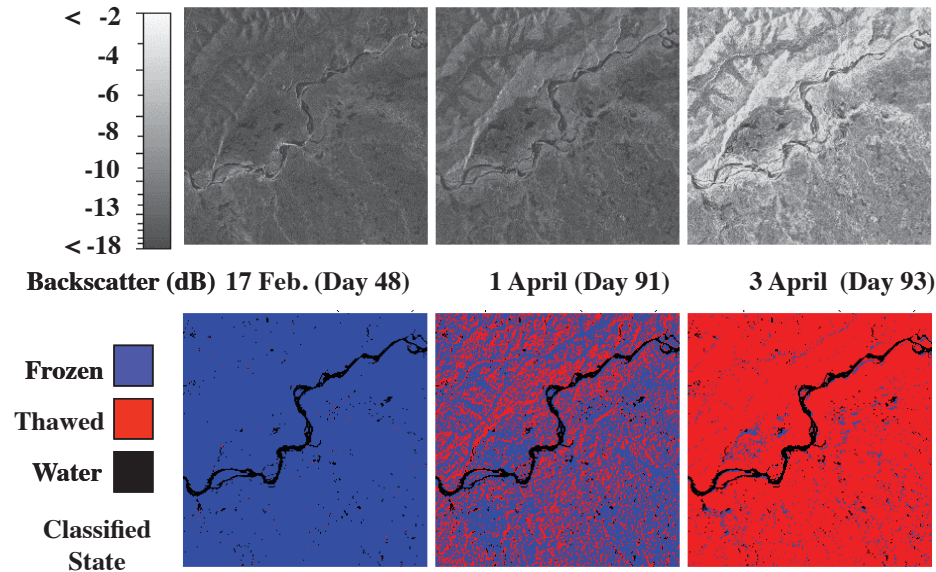
The basis of the radar freeze-thaw measurement is the large shift in dielectric constant and backscatter (*dB*) between predominantly frozen & thawed conditions. The Dielectric constant of liquid water varies with frequency, whereas that of pure ice is constant (Left);

longer (L-band) frequencies have generally greater soil-vegetation sensitivity & larger freeze-thaw signal relative to higher frequency channels.

(Courtesy of John Kimball)

Bonanza Creek Experimental Forest, Alaska

JERS -1 L-band SAR landscape freeze-thaw classification



Seasonal Threshold Algorithm

$$\Delta(t) = [\sigma^0(t) - \sigma^0_{fr}] / [\sigma^0_{th} - \sigma^0_{fr}]$$

σ^0_{fr} = frozen reference

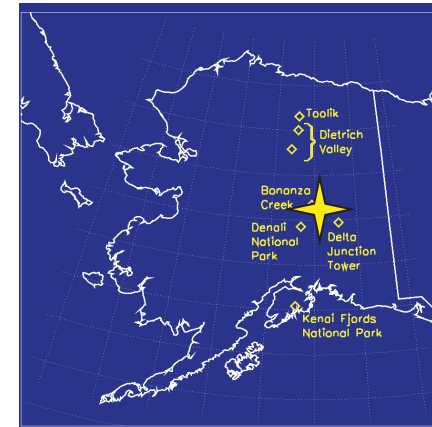
σ^0_{th} = thawed reference

T = threshold

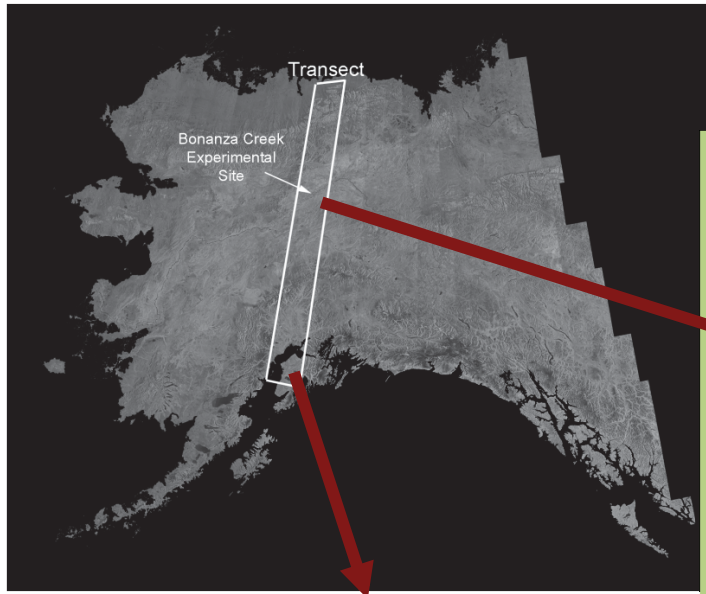
$\Delta(t) > T$ (Thawed)

$\Delta(t) \leq T$ (Frozen)

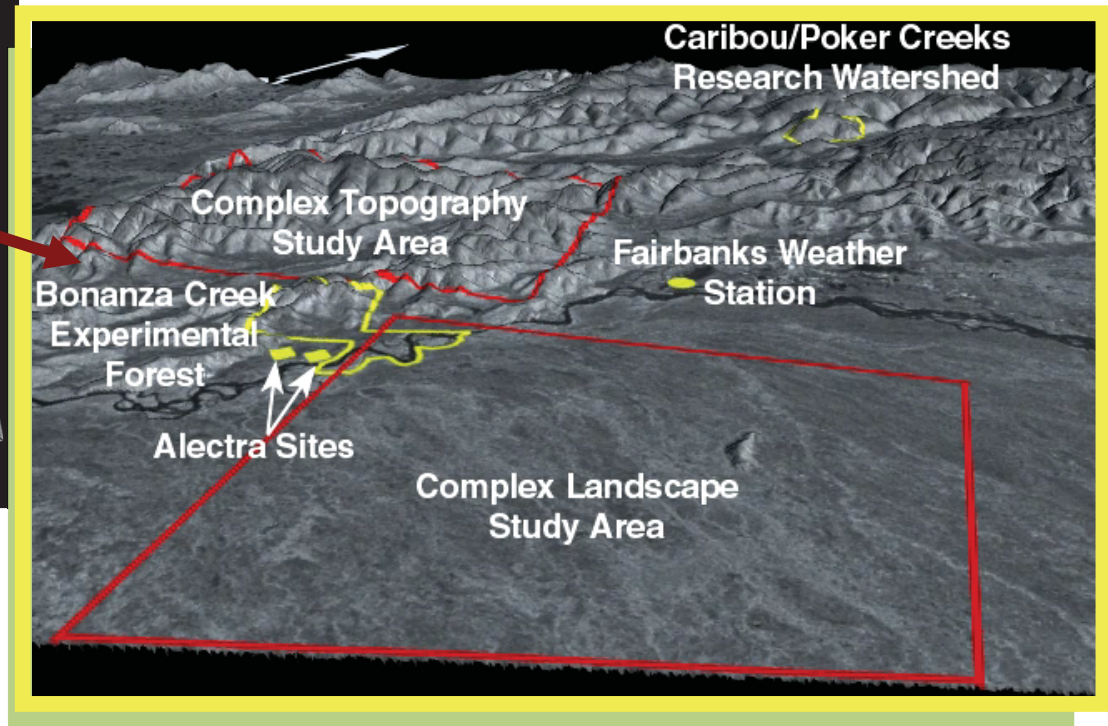
Comparison with in situ data



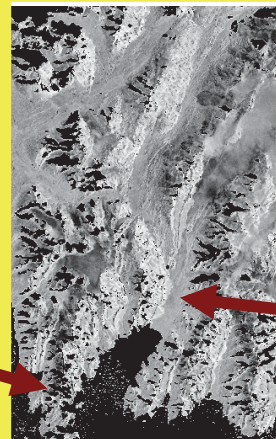
Freeze/Thaw Monitoring: Alaska



Interior Alaska



Kenai Peninsula

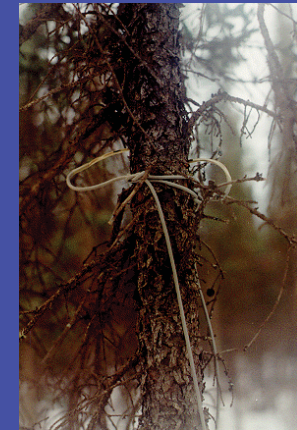
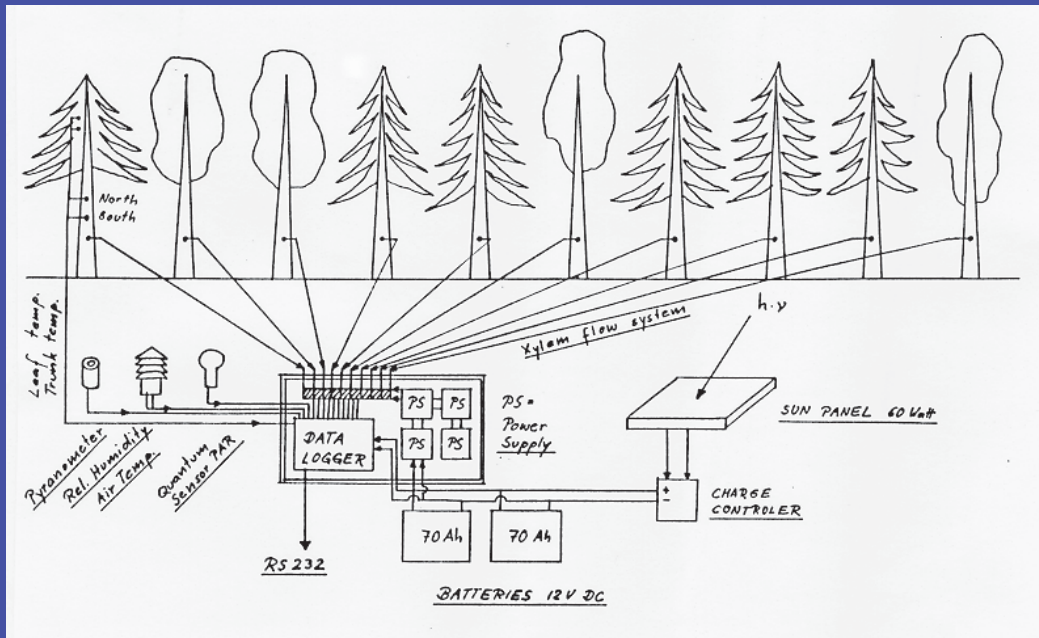


Resurrection Peninsula

Ellsworth Glacier

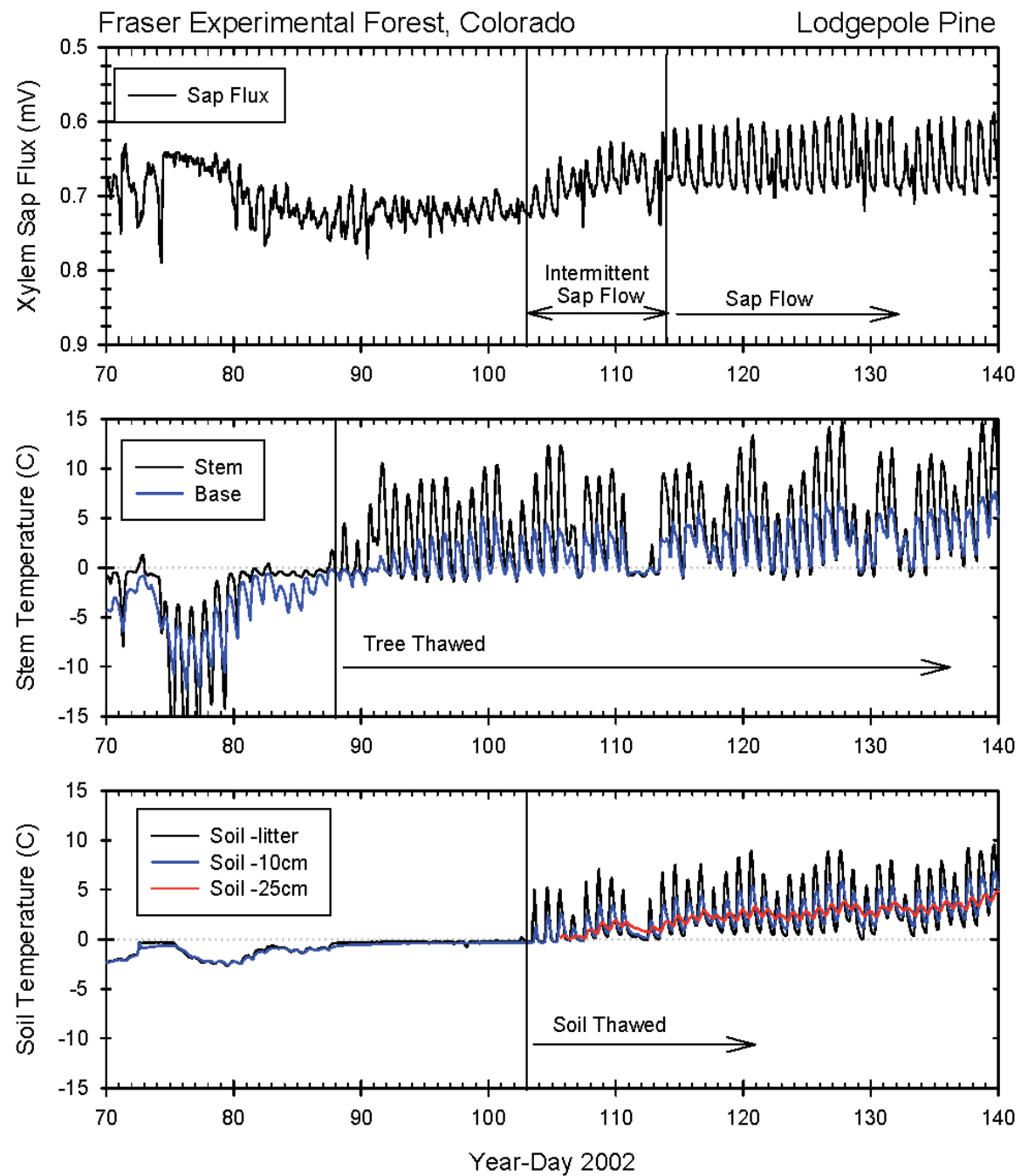


In Situ Biophysical Measurements

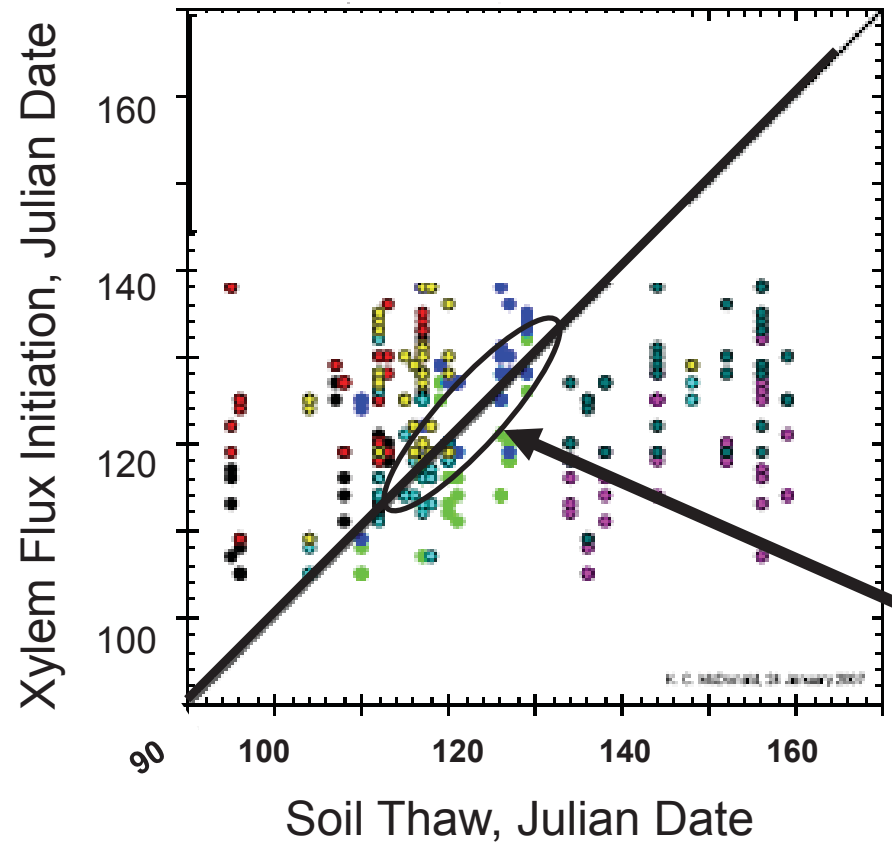


Station Set-up





BC LTER White Spruce



**X=Y line is
Best Proxy for
onset of growing
season
(litter, 10cm
important)**

Xylem Flux

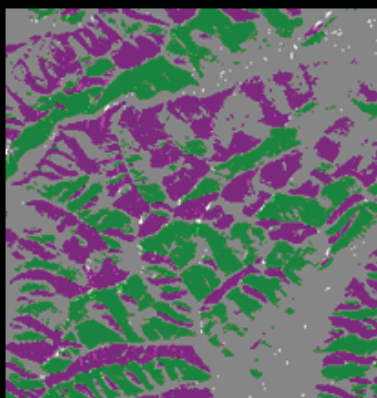
Continuous ● ●
Intermittent ● ●
Start Finish
Thaw of Litter

Xylem Flux

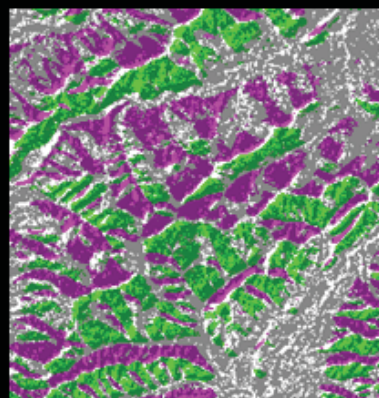
Continuous ● ●
Intermittent ● ●
Start Finish
Thaw at 10cm

Freeze/Thaw Monitoring: Enhancements

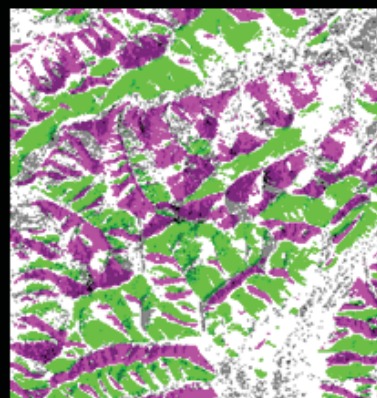
Thaw State Classifier Integrated with Landscape Topography Bonanza Creek Experimental Forest, Alaska



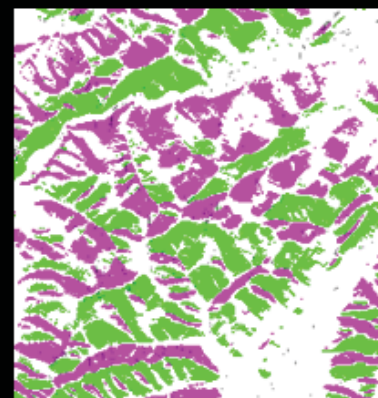
16 Feb 1998



1 April 1998

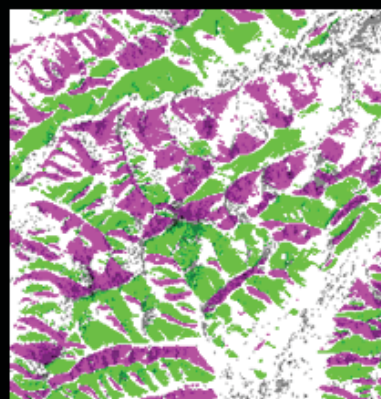


15 May 1998

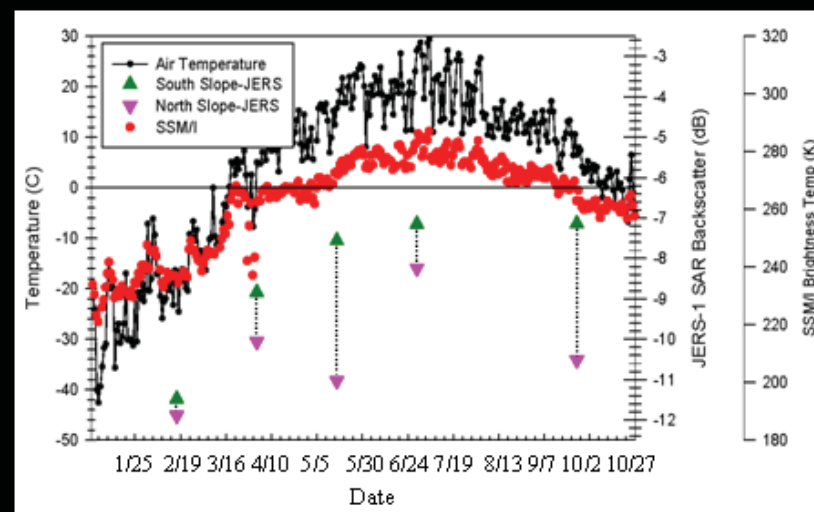


28 June 1998

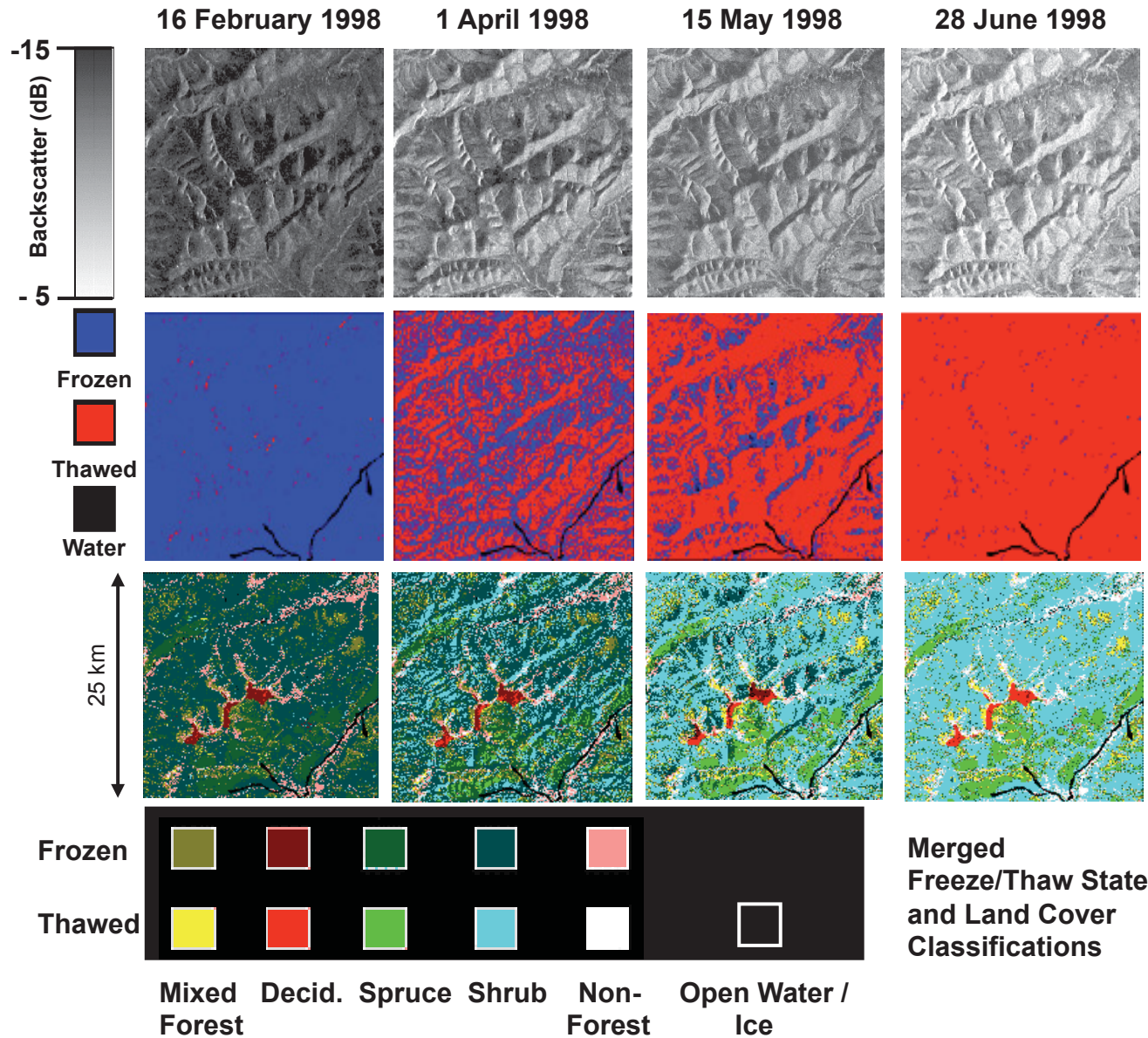
25 km



24 Sept 1998



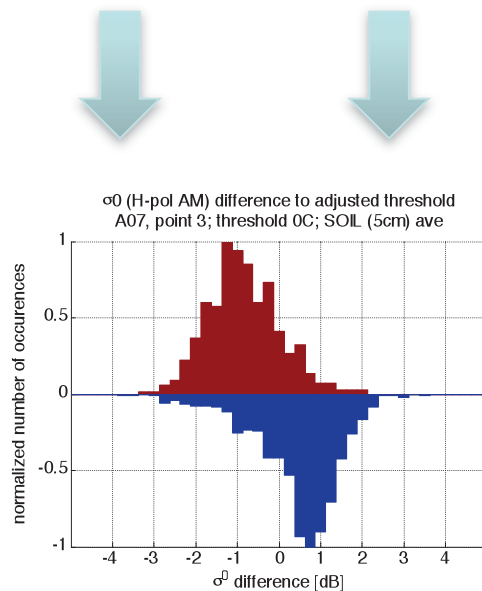
Freeze/Thaw Monitoring: Alaska



ALECTRA and QuikSCAT



- QuikSCAT backscatter analyzed vs. ALECTRA biophysical network
- Sophisticated ALECTRA data valuable for the planning efforts
- Study indicates the most significant landscape components for explaining QuikSCAT backscatter changes
- Results vary with terrain and land cover conditions which may have implications on validation planning

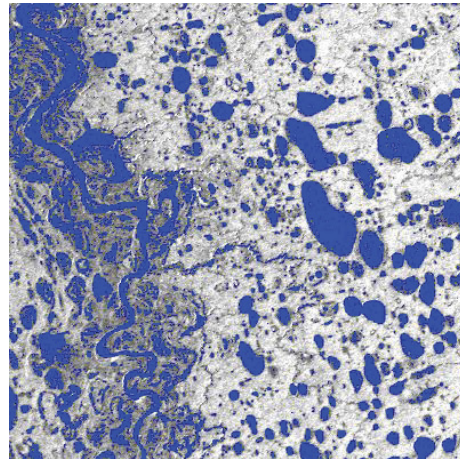


(submitted to TGRS)

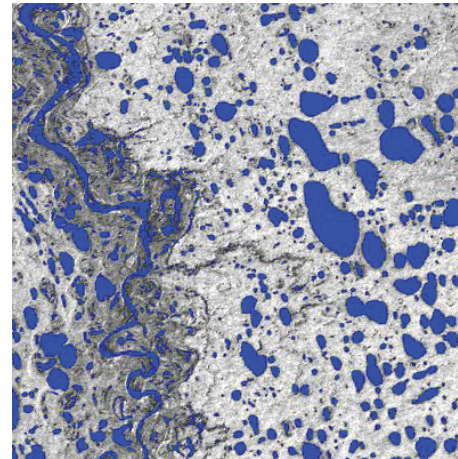
ST.	SUB	AIR	STEM	BRANCH	SOIL-5	SOIL-10	Type
A01	1	0.23	0.22	0.24	-	0.30	White Spruce
	2	0.25	0.24	-	-	0.31	Black Spruce
	3	-	0.24	-	-	0.24	Poplar
	4	0.29	0.26	0.25	-	0.23	Alder Shrub
A04	1	0.18	0.17	0.16	-	0.25	Sitka Spruce/Poplar
	2	0.17	0.14	0.16	0.21	-	Alder
A05	1	0.26	0.24	-	-	0.37	Open Shrub (Willow)
	2	0.23	0.24	0.25	-	0.23	White Spruce
A06	1	0.29	0.29	0.29	-	0.34	White Spruce/Balsam Poplar
A07	1	0.25	0.24	0.29	0.24	-	Black Spruce bog
	2	0.24	0.25	0.22	0.23	-	Black Spruce, north slope
	3	0.24	0.25	0.22	0.21	-	White Spruce, south slope
	4	0.26	0.25	0.23	0.30	-	Open Shrub/Bog (Willow)
A08	1	0.26	0.26	0.27	0.23	-	White Spruce
	2	0.26	0.29	0.25	0.23	-	Open Shrub (Willow)
	3	0.29	0.26	0.28	0.24	-	Open Shrub, sloped (Willow)
	4	0.26	0.27	0.23	0.29	-	Open Shrub, Sandy soil
A09	1	0.26	0.23	-	-	0.20	Birch, south slope
	2	0.22	0.23	-	-	0.27	Black Spruce/Larch bog
	3	0.22	0.23	-	-	0.21	White Spruce, hill base

Open Water Change- North Slope, Alaska

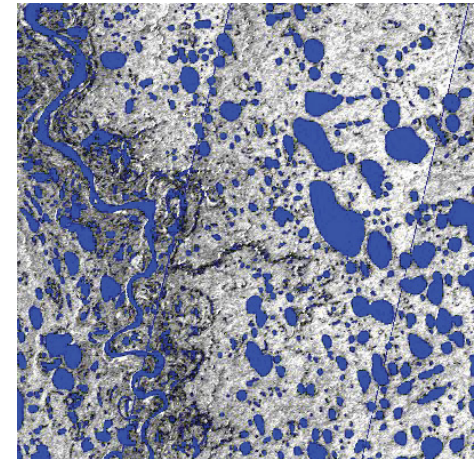
The top shows open water overlaid on the JERS image and the bottom shows open water change relative to June.



June 1998



July 1998

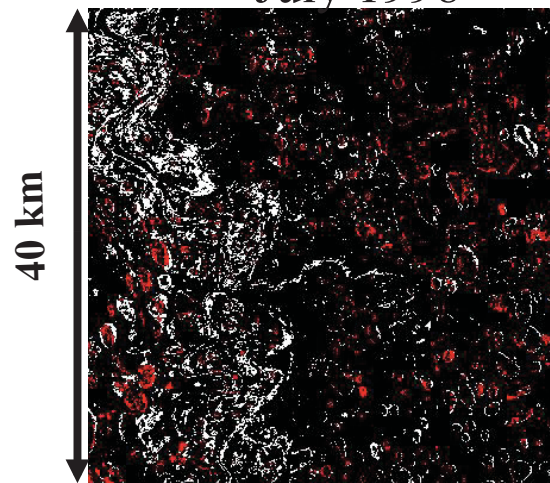


August 1998

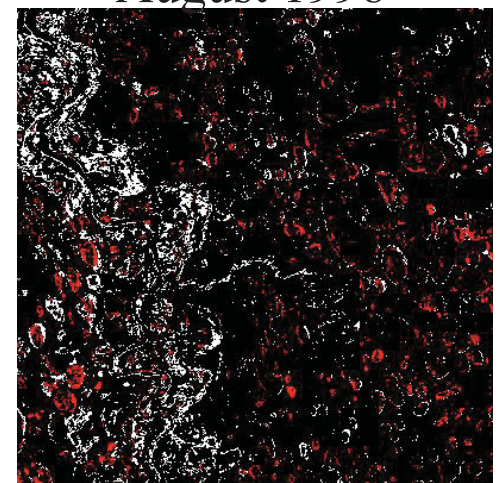
- More open water
- Less open water
- No change

Open Water Change Relative to June

	<u>Dryer</u>	<u>Wetter</u>
Jul.	7.7%	2.7%
Aug.	6.9%	3.2%



Open water change June/July



Open water change June/August

ISSUES RELATED with such a FIELD CAMPAIGN

- *Interannual variability of the transition period – need to be sure to capture it... (risk element)*
- *Spatial heterogeneity (different for the freezing and thawing transitions)*
- *Open water fractional coverage*
- *Snow on the ground (possibly melting)*
- *Freezing and thawing transitions occur differently*
- *Pre-launch cal-val of an algorithm based on time series*

MORE SPECIFIC OBJECTIVES

- *Evaluate / calibrate specific elements of the SMAP F/T retrieval algorithm for the subarctic environment.*
- *Document errors associated with the SMAP F/T state retrieval based on L-band active data.*
- *Evaluate algorithms to monitor F/T at medium and low resolution over the Tundra and the Boreal Forest in Canada (based on passive MW measurements).*

STUDY AREA

- *Near the village of Umiujaq, on eastern shore of Hudson Bay (Qc) Canada (56° N, 76.31° O).*
- *Complex landscape, including lakes, wetlands, marine, coastal, riparian, permafrost, streams.*
- *Discontinuous permafrost*
- *Located at the tree line limit.*



Nunavik map

Source : Makivik Corporation

The CEN Network



8 field stations
75 climate stations

CENTRE D'ÉTUDES NORDIQUES
CEN Centre for Northern Studies

More than 20 years of study on this region by the Center for Northern Studies (CEN)

Climate stations, part of the CEN SILA network and permafrost

5 meteorological stations operated by CEN near Umiujaq, equipped with soil temperature probes for monitoring the permafrost

Ward Hunt Island, 83°N

Bylot Island, 73°N

Salluit, 62°N

Boniface, 58°N

Umiujaq & LEC, 56°N

Kuujuarapik, 55°N
Whapmagoostui

Radisson, 53°N

Quebec City
CEN secretariat
and data centre
at Laval University

CURRENT CLIMATE over the AREA

- *60 to 80 frost-free days per year*
- *Annual average air temperature: -5.5°C*
- *Annual precipitation of about 500 mm*
- *37% of precipitation as snowfall (in terms of amount)*
- *Annual average wind speed is 20-24 km/h*
- *Windchill as severe as -60°C*

OVERALL OBSERVATIONAL APPROACH

SPACE-BASED

RADARSAT2, AMSR-E, SMOS, SAOCOM?,
Aquarius? ALOS

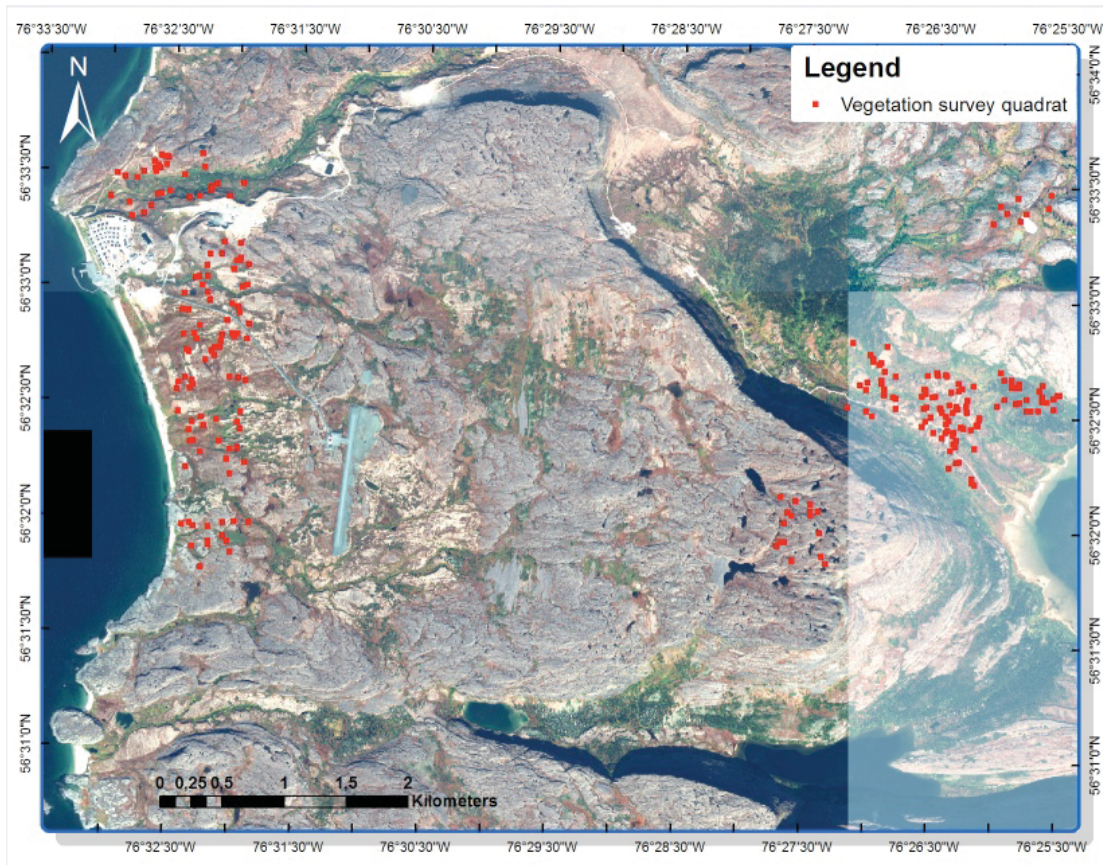
AIRBORNE

NASA UAVSAR L-band radar (Gulfstream-III)
EC L-band radiometer (Twin Otter or Polar 6)

GROUND

Long-term network (soil temperature sensors)
Additional field-phase ground measurements

VEGETATION SURVEYS



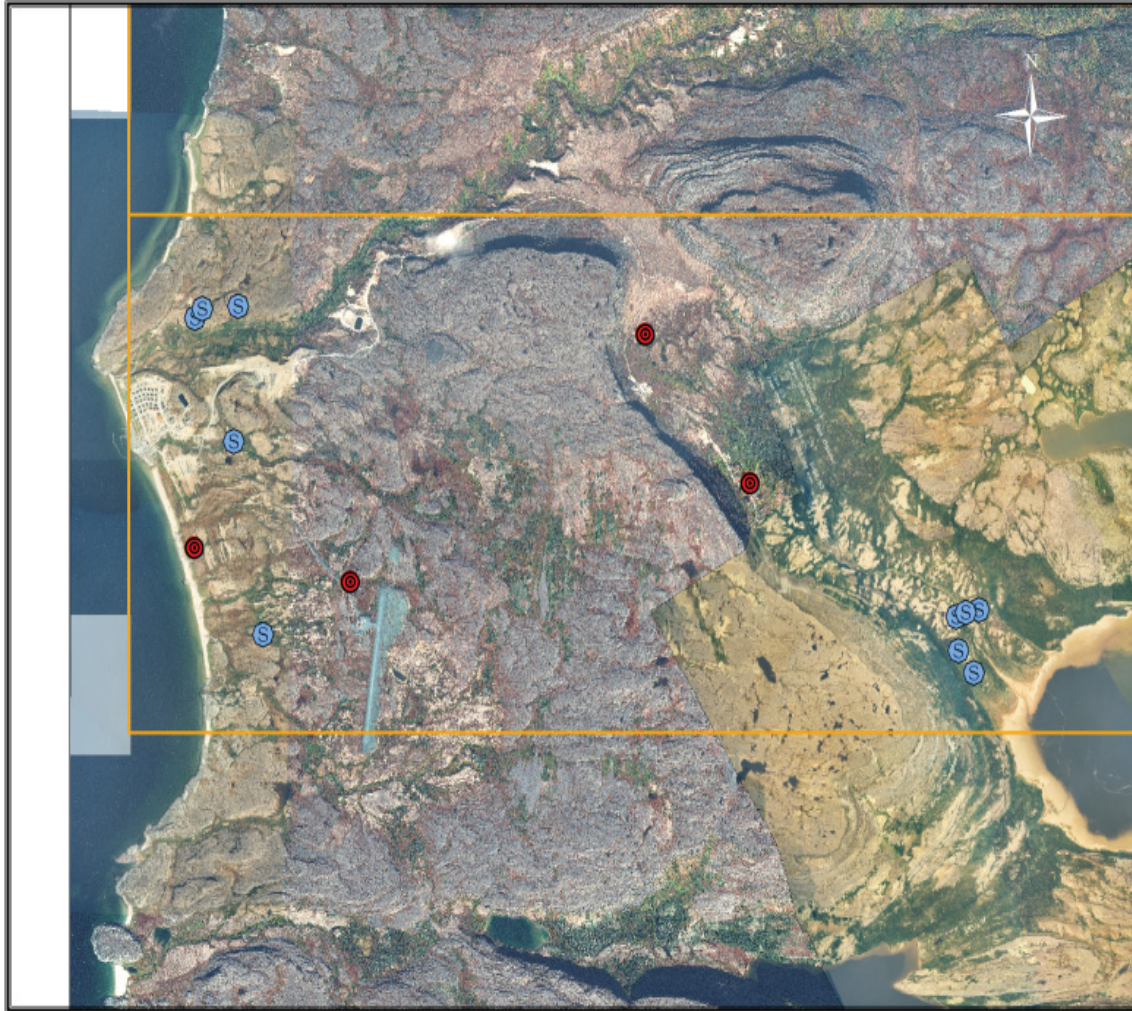
Spatial coverage of the vegetation surveys performed in summer 2008 and 2009 (red dots) near Umiujaq (Hudson Bay area) in Northern Quebec, Canada.

Three sub-arctic (hemi-arctic) environments: a coastal area characterized by sparse tundra vegetation, a valley area covered with shrubby vegetation and black spruce trees, a second valley (north half of the area) dominated by thermokarst lakes and hollows.

A vegetation survey has been done by INRS collaborators (CEN) in summer 2008 and 2009. More than 200 quadrants (5m x 5m) have been inventoried: Vegetation cover %, Habitat, Moisture (qualitative), Substrata types, Topographic position, Vegetation species (20) and Vegetation Height (m)

Satellite data (Ikonos 2005, Geoeye 2009, TerraSAR-X (since 2009), RADARSAT-2 since 2010, DEM) have also been examined.

GROUND NETWORK



Blue: soil temperature sensors (10)

Red: Weather stations (5)

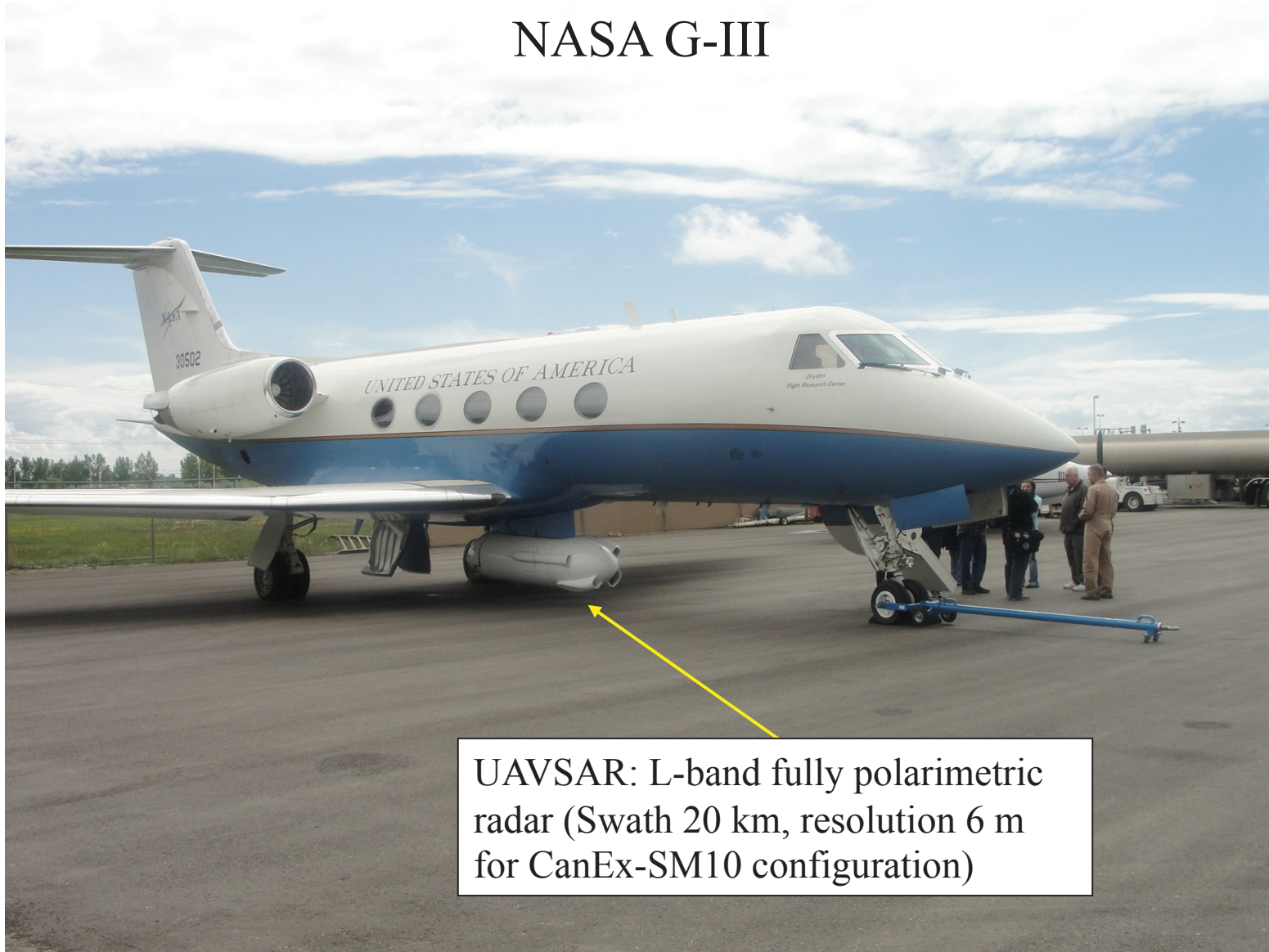
Additional temperature and TDR probes will be installed by INRS in the Sheldrake River watershed during the summer prior to the F/T experiment.

In conjunction with the flights conducted during the field phase of the experiment, field teams will take pictures of the soil and vegetation conditions and will take some measurements on the soil status (frozen or not) and soil characteristics (moisture, density) as well as snow cover depth (number of teams TBD)

Vegetation survey quadrates could be done for the Sheldrake River watershed in summer 2012.

UAVSAR L-Band RADAR

NASA G-III



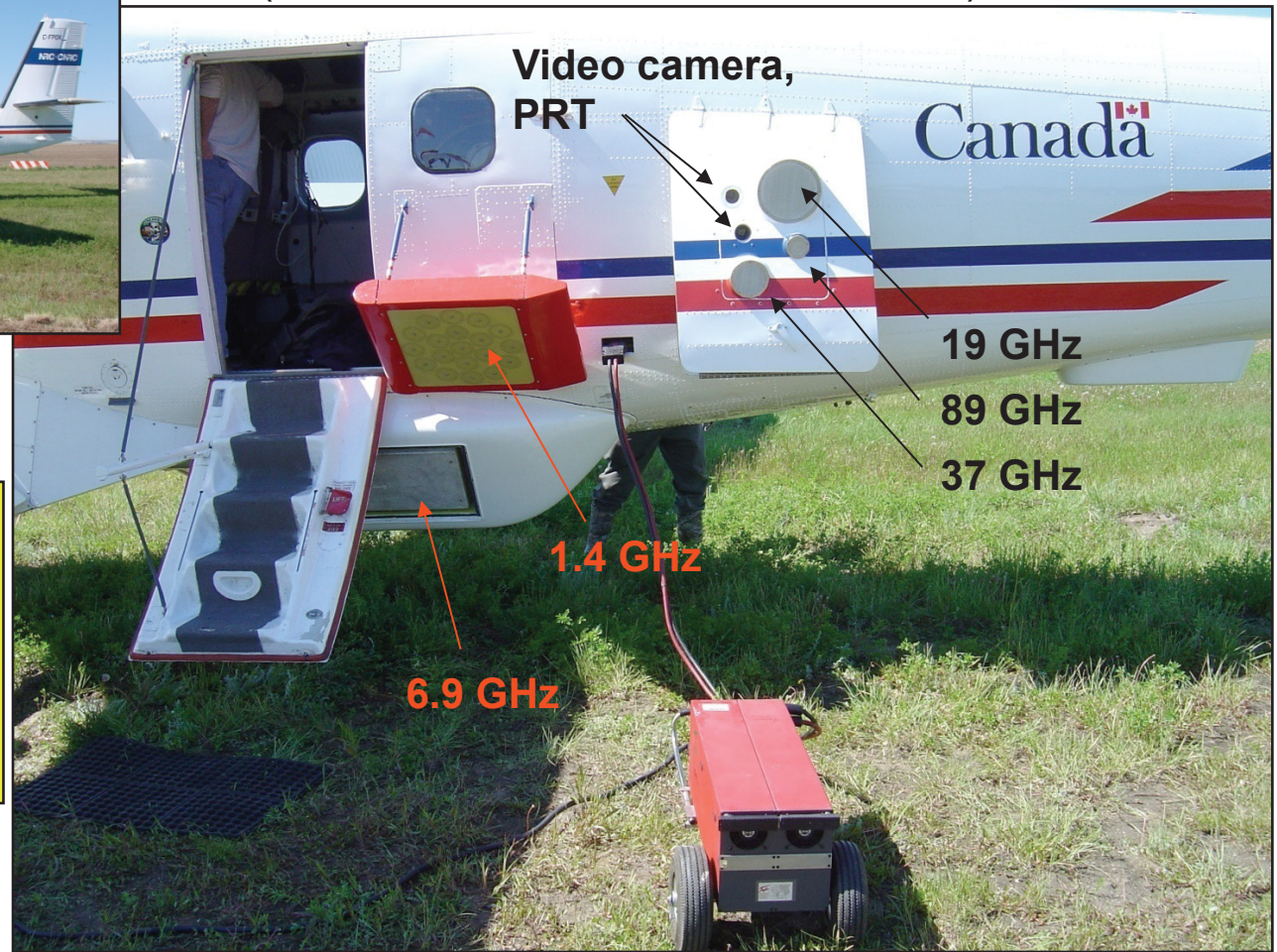
UAVSAR: L-band fully polarimetric radar (Swath 20 km, resolution 6 m for CanEx-SM10 configuration)

EC's L-Band **RADIOMETER**

NRC Twin Otter

(As mounted on NRC's Twin Otter)

- 6.9, 19, 37 and 89 GHz → 53° incidence angle
- 1.4 GHz → 40° incidence angle



Another aircraft (e.g., Polar 6) may be used for the F/T campaign

PERIOD of the FIELD CAMPAIGN (FALL 2012 vs SPRING 2013)

Freezing (fall) or thawing (spring) portions of the annual cycle?

Fall 2012 could be just after SMAPVEX 2012 (a few months only)

Spring 2013 would be closer to launch. More useful as a rehearsal for the post-launch campaign.

FY13 in the US, FY12/13 or FY13/14 in Canada

Other considerations: aircraft / instrumentation / resources availability, fuel transport for spring campaign.

WEATHER CONSIDERATIONS FOR MICROWAVE RADIOMETER AIRCRAFT OPERATIONS

Summary of Aviation Weather Analysis for Umiujaq Study Site

	Fall Freeze-up Period	Spring Thaw Period
Frequency of cloud ceilings below 10,000 ft	92%	61%
Probability of flight operations (suitable landing conditions)	67% (54% - IFR, 13% - VFR)	87% (48% - IFR, 39% - VFR)

- Spring thaw period has higher chance of flight operations and VFR conditions
- Fall freeze-up period is doable but managing flight operations will be difficult
- More flight hours will be required for fall period due to high probability of IFR conditions – likely not possible to cover Umiujaq study area in one flight
- Use of Polar 5/6 aircraft will allow longer flight times over study area due to longer flight duration (still subject to same landing and operating restrictions as Twin Otter)
- Availability of NRC Twin Otter and Polar-5/6 for Fall 2012 or Spring 2013 is uncertain at this time

EXPECTED DATASETS

Datasets	Description	Provider
UAVSAR	L-band backscatter	T. Jackson (USDA)
EC's radiometers	Tb at 1.4, 6.9, 19, 37, and 89 GHz	A. Walker (EC)
Satellites...	PALSAR, SAOCOM (to be launched), RADARSAT2, AMSR-E, SMOS	
Ground network	Tsoil, soil moisture, soil density, F/T state, vegetation	M. Bernier (INRS-ETE)
Ground measurements	Soil state (F/T), vegetation (photographs), soil density, Tsoil, soil moisture, ...	M. Bernier (INRS-ETE)
Sites characteristics	Vegetation state and characteristics during the experiment, topography, water fractional coverage, roughness	M. Bernier (INRS-ETE) K. McDonald (JPL / CCNY)
Meteorology	Air temperature, humidity, winds, precipitation (snow / rain)	M. Bernier (INRS-ETE) S. Belair (EC)

PARTICIPANTS

(Planification and Implementation)

INRS-ETE (CEN):

- M. Bernier: Coordination field campaign, Algorithms development
- P. Kalantari: Algorithm development for F/T Product, Field work
- J. Poulin: Logistics, field work

Environment Canada (EC):

- A. Walker: Aircraft and instruments
- S. Belair: Coordination

SMAP Project:

- T. Jackson (USDA): UAVSAR, coordination
- K. McDonald (City College of New York / JPL)
- A. Colliander (JPL)

FUNDING PLAN

UAVSAR

SMAP Project

RADIOMETERS

**CSA Government Related Initiatives
Program**

***GROUND
ACTIVITIES***

**CSA Earth Observation Applications
and Utilizations (EOAU) grants
programs**

... plus in-kind from the participating organisations.

REMAINING ISSUES

Enough ground observations? Best site in Canada? Too close to Hudson Bay?

Cal / Val of a retrieval algorithm based on long time series (emphasis on preparations for a post-launch validation campaign)

Period of the campaign (Fall 2012 or Spring 2013); need to capture F/T transitions.

Logistical considerations related to northern field studies (fuel transport, road access, accommodations, airport with hangar, de-icing for aircraft).

Weather (for Twin Otter or Polar 6 aircraft measurements).

Collaborations

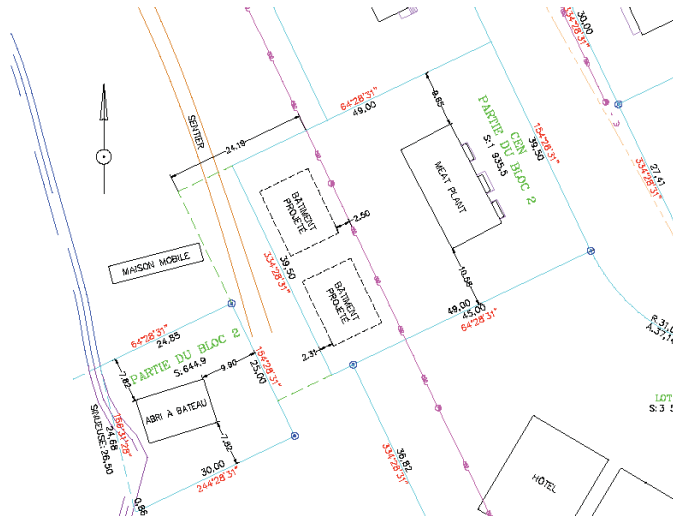
BACKUP SLIDES

WEATHER CONSIDERATIONS FOR MICROWAVE RADIOMETER AIRCRAFT OPERATIONS

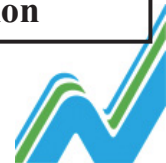
- Location of Umiujaq study area along coast of Hudson Bay – complicating weather conditions for flight operations, especially for fall period when Hudson Bay is ice-free (persistent cloud, freezing drizzle, low visibilities)
- Proposed aircraft base – Kuujjuarapik (86 nautical miles south of study area)
- Analysis carried out for 2006-2010 aviation weather conditions during fall freeze-up period (mid-October to mid-November) and spring thaw period (May)
- Ideal operations – minimal cloud below 10,000 ft, Visual Flight Rules (VFR) conditions (visibility > 1 mile)
- VFR operations maximizes flight time available over study area (~3.2 hours with Twin Otter)
- Instrument Flight Rules (IFR) operations, when significant cloud is present, reduces flight time over the study area to 1.5-2 hours due to fuel reserves required for alternate airport landing (100-150 nm southeast of Kuujjuarapik)
- Kuujjuarapik is an uncontrolled, single runway airport therefore pilot may want to keep fuel reserve in case of landing delays (unexpected aircraft, vehicles or animals on runway)
 - Flight time over study site reduced to 2.75 hours (VFR operations)
 - If pilot requires alternate landing airport as contingency, flight time over the study area is further reduced to 2.2 hours (VFR operations)

Umiujaq CEN station, 56°N

house, garage, warehouse



Partnerships:
Kativik Regional Government,
Nunavik Research Centre (Makivik Corporation)
Local Annituvik Land Holding Corporation



LOGISTICS at UMIUJAQ

Local transportation available:

- 4x4 trucks,
- Snowmobiles,
- ATVs.

Fuel Availability via CEN.

Power: Regular commercial.

Nearest Medical Services:

- Health Centre in Umiujaq.
- Hospital in Puvirnituk.

External transport:

- Daily flights available from Montreal (Qc) via Whapmagoostui-Kuujuarapik
- Helicopter service (charter) available from Radisson



Radisson Ecological Research Station
53°N
La Grande River Airport - CYGL
up to 20 persons (3 houses)



CENTRE D'ÉTUDES NORDIQUES

CEN Centre for Northern Studies

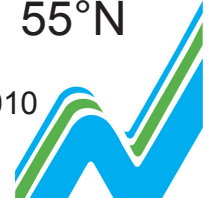


Community Science Centre at Whapmagoostui- Kuujjuarapik 55°N

CYGW

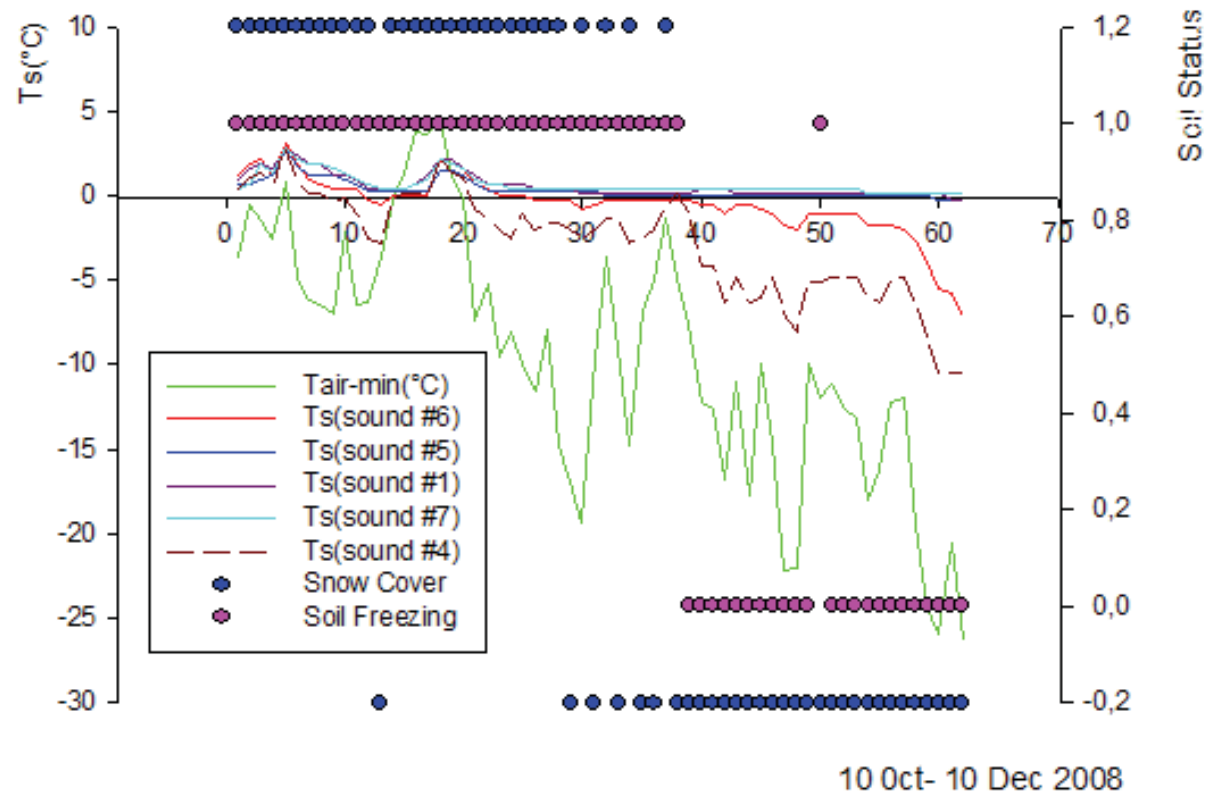
Photos: Sept./Oct. 2010

Completion by
January 2011

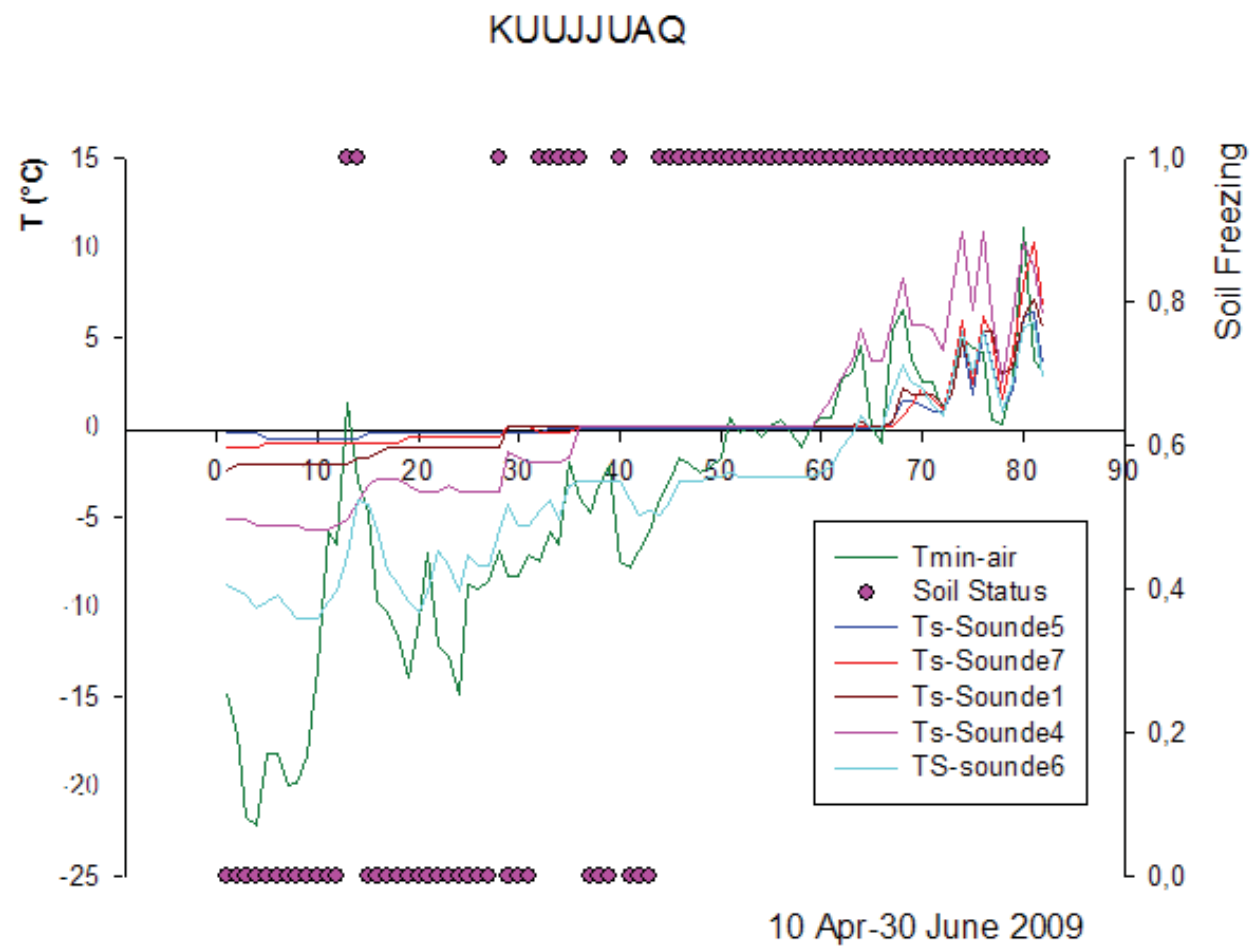


Freezing Fall 2008

Soil temperature sensors have been installed by INRS near the soil surface in summer 2010 for 2010, 2011, and 2012 to monitor soil temperature through the year. KUUJJUAQ



Thawing Spring 2008



SPATIAL VARIABILITY

Field conditions in 2010



Weather conditions during 2010 winter exceptionally warm... No snow May 4

Patches of snow on May 7, 2010



Frequency of Suitable Flying Conditions (IFR) for Kuujjuarapik

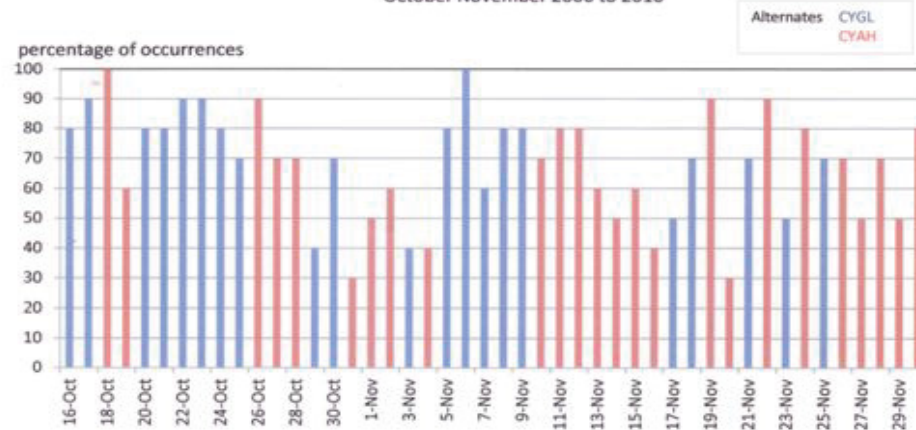
Blue – 1.58 hrs. of
flight time over study
area

Red – 2 hrs. over of
flight time over study
area

FALL

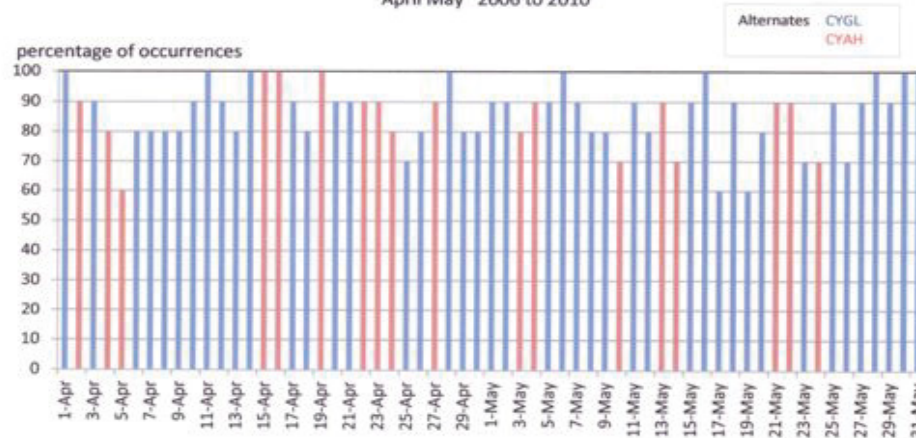
CYGW Suitable Flying Conditions
October November 2006 to 2010

Attachment 3



SPRING

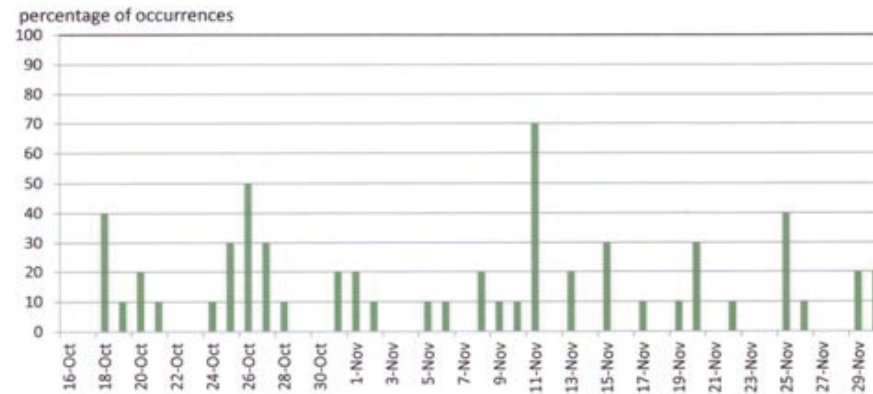
CYGW Suitable Flying Conditions
April May 2006 to 2010



Note: Graphs are for suitable weather conditions from 8:00 am to 7:00 pm at both Kuujjuarapik and the most usable alternate airport.

FALL

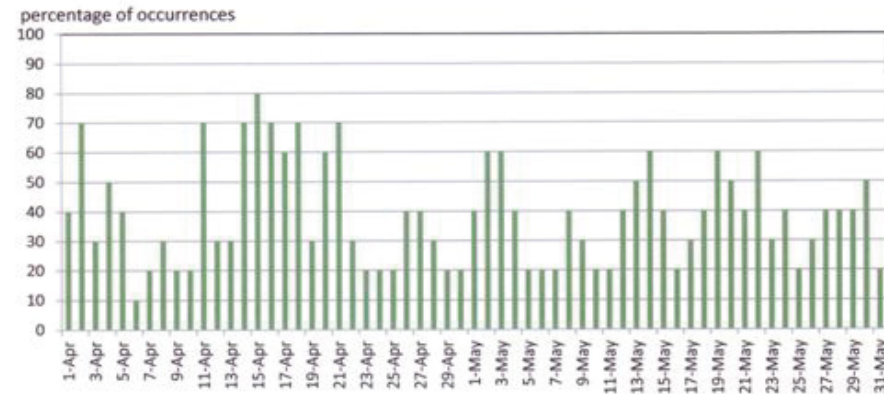
VFR Days at Umiujaq (at 10,000 feet) and at Kuujjuarapik
October November - 2006 to 2010



Frequency of VFR Conditions for Flight Operations over Umiujaq Study Area

SPRING

VFR Days at Umiujaq (at 10,000 feet) and at Kuujjuarapik
April May - 2006 to 2010

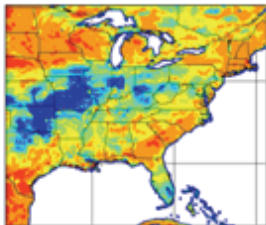
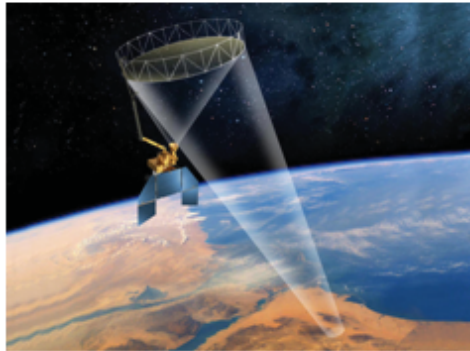


REMINDER: SMAP PRODUCTS

Product	Short Description	Resolution/ Grid	Latency	
L1A_S0	Radar raw data in time order	–	12 hours	Instrument Data
L1A_TB	Radiometer raw data in time order	–	12 hours	
L1B_S0_LoRes	Low resolution radar σ_o in time order	5x30 km	12 hours	
L1B_TB	Radiometer T_B in time order	36x47 km	12 hours	
L1C_S0_HiRes	High resolution radar σ_o	1-3 km	12 hours	
L1C_TB	Radiometer T_B	36 km	12 hours	
L2_SM_A	Soil moisture (radar)** [research product]	3 km	24 hours	Science Data (Half-Orbit)
L2_SM_P	Soil moisture (radiometer)	36 km	24 hours	
L2_SM_A/P	Soil moisture (radar/radiometer)	9 km	24 hours	
L3_SM_A	Soil moisture (radar)	3 km	24 hours	Science Data (Daily Composite)
L3_F/T_A	Freeze/thaw state (radar)	3 km	50 hours	
L3_SM_P	Soil moisture (radiometer)	36 km	50 hours	
L3_SM_A/P	Soil moisture (radar/radiometer)	9 km	50 hours	
L4_SM	Soil moisture (surface & root zone)	9 km	7 days	Science Value-Added
L4_C	Carbon net ecosystem exchange (NEE)	9 km	14 days	

CANADIAN PLAN for SMAP

Canadian Science and Applications Plan for the Soil Moisture Active and Passive Mission



November 2010

 Environnement Canada Environment Canada



OBJECTIVES:

Cal / Val (SM and FT products)

Research, development, and applications
(retrievals, data assimilation, products – for SM, FT, and NEE)

COMPONENTS and PARTICIPANTS:

Cal/Val soil moisture (core sites, campaigns):
EC (MRD,CRD,HAL), AAFC, NRC, Guelph,
Sherbrooke, SMAP

Cal/Val FT (sites, campaigns): EC (MRD,CRD),
NRC, INRS-ETE, SMAP

Soil moisture and FT retrievals: AAFC,
Sherbrooke, INRS-ETE

Soil moisture and FT data assimilation:
EC(MRD), Guelph

Carbon cycle analysis: EC(MRD,CRD), U. of
Toronto

Impacts, products, operations:
EC(MRD,MSC)

SMAP F/T ALGORITHM BASELINE

Seasonal threshold Approach (Baseline Algorithm):

$$\Delta(t) = \frac{\sigma(t) - \sigma_{fr}}{\sigma_{th} - \sigma_{fr}} \quad \begin{array}{ll} \Delta(t) > T & \text{Thawed} \\ \Delta(t) \leq T & \text{Frozen} \end{array}$$

Seasonal threshold Approach (Enhanced Baseline Algorithm):

$$\Delta(t) = \sigma(t) - \left\{ \sigma_{fr} + (\sigma_{th} - \sigma_{fr})T \right\}$$

$$\Delta(t) > 0 \quad \text{Thawed}$$

$$\Delta(t) \leq 0 \quad \text{Frozen}$$

(Courtesy of John Kimball)

Source: McDonald, K.C, and J.S. Kimball, 2005. Encyclopedia of Hydrological Sciences. DOI: 10.1002/0470848944.hsa059a.

The SMAP mission has not been formally approved by NASA. The decision to proceed with the mission will not occur until the completion of the National Environmental Policy Act (NEPA) process. Material in this document related to SMAP is for information purposes only. The research described in this publication was carried out in part at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration. © 2011. All rights reserved.